Climatology, seasonality and trends of oceanic coherent eddies

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Key Points:

- Kinetic energy climatology reveals a surprising heterogeneity in the global ocean.
- Transient kinetic energy show significant increasing trends over large areas of the Southern Ocean and the Northern Hemisphere.
- Regional kinetic energy climatology strongly depends to the region dominant oceanic process.

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Abstract

Ocean eddies influence regional and global climate through mixing and transport of heat and properties. One of the most recognizable and ubiquitous feature of oceanic eddies are vortices with spatial scales of tens to hundreds of kilometers, frequently referred as "mesoscale eddies" or "Coherent eddies". Coherent eddies are known to transport properties across the ocean and to locally affect near-surface wind, cloud properties and rainfall patterns. Although coherent eddies are ubiquitous, yet their climatology, seasonality and long-term temporal evolution remains poorly understood. Thus, we examine the kinetic energy contained by coherent eddies and we present the annual, interannual, and long-term changes of automatically identified coherent eddies from satellite observations and a state of the art numerical simulation from 1993 to 2018. Satellite observations show that around 40% of the kinetic energy contained by ocean eddies corresponds to coherent eddies. Additionally, a strong hemispherical seasonal cycle is observed, on top of a 3–6 months lag between the wind forcing and the response of the coherent eddy field. Furthermore, the seasonality of the number of coherent eddies and their amplitude reveals that the number of coherent eddies responds faster to the forcing ($\sim$3 months), while the coherent eddy amplitude is lagged by $\sim$6 months. There are regions that show a pronounced influence of coherent eddies, notably, the East Indian Ocean, the East Tropical Pacific Ocean, and the South Atlantic Ocean. In these locations, a strong seasonal cycle and interannual variability can be observed in both satellite and numerical models. Although, there is agreement between these products on the seasonality of the number of eddies, the seasonality of the coherent eddy amplitude between these products show some inconsistencies. Long-term trends of the coherent eddy amplitude from satellite observations and the state of the art model show significant increases in the eddy amplitude of $\sim$3cm per decade in large portions of the ocean, while the number of coherent eddies remains constant. Our analysis highlight the relative importance of the coherent eddy fiend in the ocean kinetic energy budget, imply a strong response of the eddy number and eddy amplitude to the surface wind at different time-scales, and showcases for the first time seasonality, and multidecadal trends of the coherent eddy properties.

Plain summary

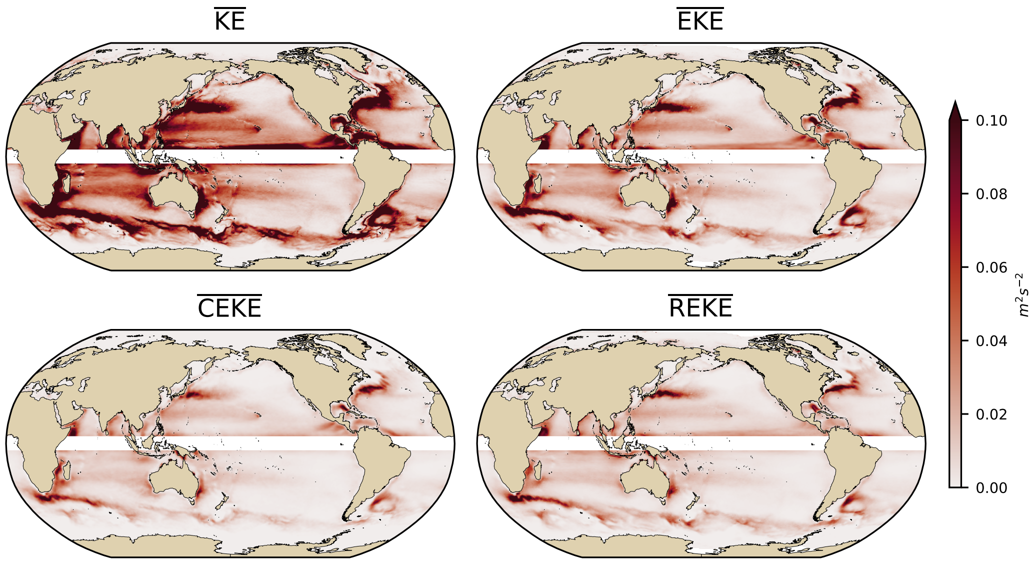

Figure 1. Caption

- Ratios of KE!! - Coherent signature + seasonality and non-coherent signature (not key point) - Identify regions dominated by coherent eddies

1 Introduction

Ocean currents are highly anisotropic and include coherent vortices and meandering jets. While coherent vortices (recirculating currents) are approximated as ellipses with axes smaller than the Rossby radius of deformation (R_D), meandering jets are narrow but elongated currents. The anisotropic nature of these features translates in ...

2 Methods

3 Results

3.1 Coherent Eddy Energetics

3.1.1 Global

- Figure 1 shows regions with high values of Kinetic Energy at the Western Boundary Currents, ACC, and ocean gyres.
- $\overline{\mathrm{EKE}}$ Explains 70% of $\overline{\mathrm{KE}}$, while $\overline{\mathrm{CEKE}}$ is 40% of $\overline{\mathrm{EKE}}$ and $\overline{\mathrm{REKE}}$ is 60% of $\overline{\mathrm{EKE}}$

- Maps show that $\overline{\mathrm{KE}}$, $\overline{\mathrm{EKE}}$, $\overline{\mathrm{CEKE}}$, and $\overline{\mathrm{REKE}}$ are dominated by the western boundary currents, the Antarctic Circumpolar Current (ACC).

3.1.2 Seasonality

3.2 Coherent Eddy Statistics

3.2.1 Global

Make sure to mention dipoles in the boundary currents.

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3.2.2 Seasonality

3.3 Regional

Number 295.85546403962104 Pos amp 0.12094501820533601 Neg amp -0.1385068018754378 Chelton Number 236.7010877964295 Chelton Pos amp 7.779538694987785 Chelton Neg amp -10.075637745571715 ACCESS Number 315.24697840283096 ACCESS Pos amp 0.0875635001289238 ACCESS Neg amp -0.08147261526708122

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Overall, we observe a polewards decrease in the number of the eddies. This supports the idea that the satellite observations are consistent with a continue dataset.

Global - Climatology - Seasonality

Regions Individual regions

Show positive vs negative amplitudes

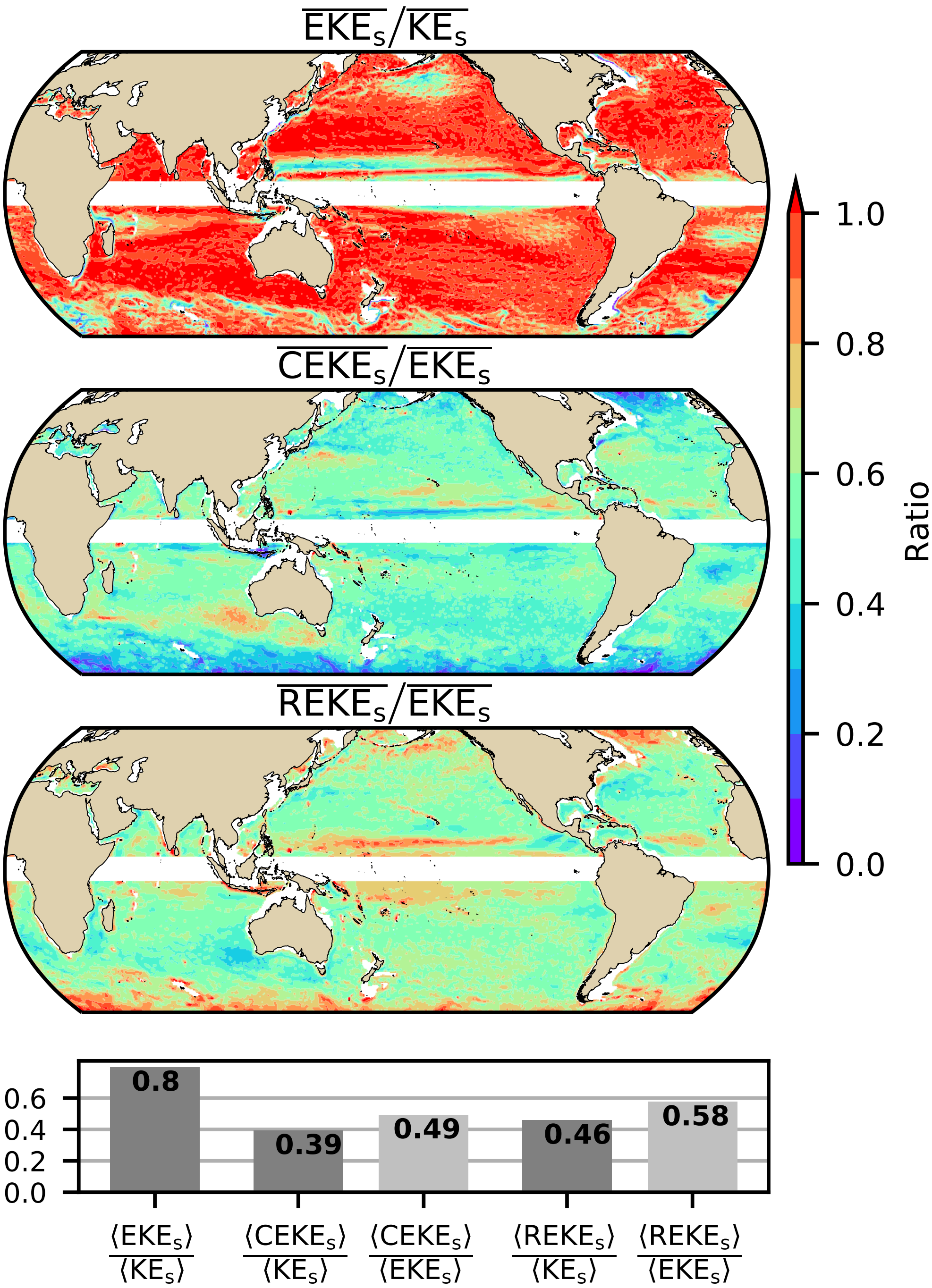

Figure 2. Ratios of the kinetic energy components. a)

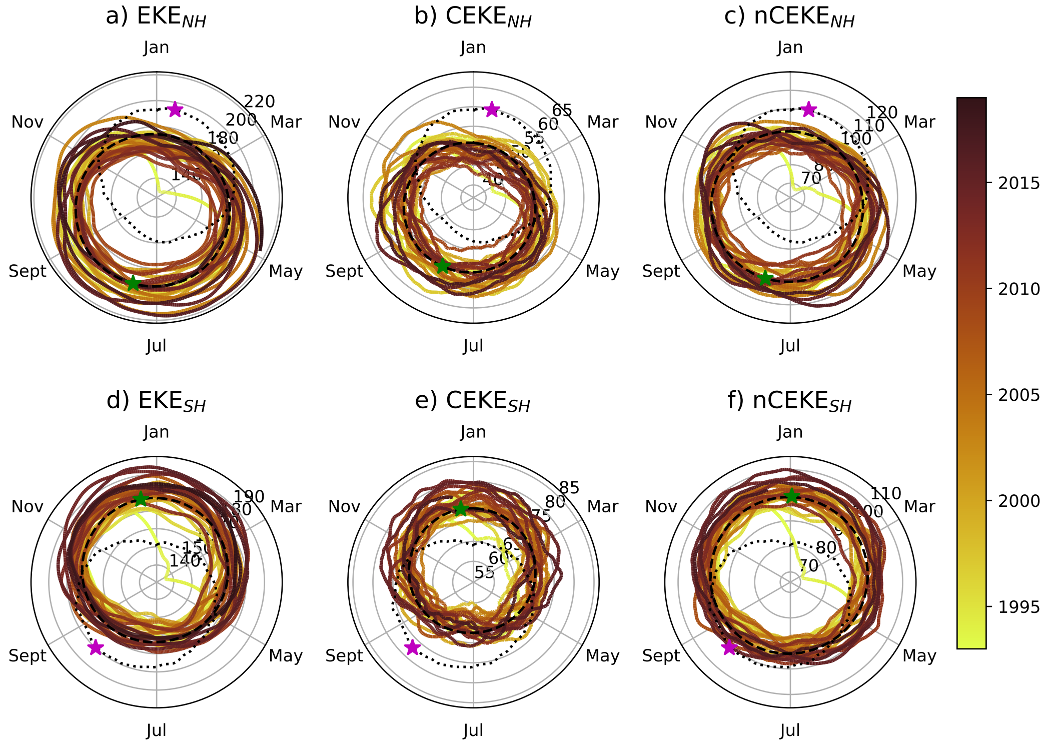

Figure 3. Dashed lines correspond to the seasonal climatology of the fields. Dotted lines show the climatology of the wind magnitude. The green and magenta stars show the maximum of the seasonal cycle for the kinetic energy components and the wind magnitude, respectively.

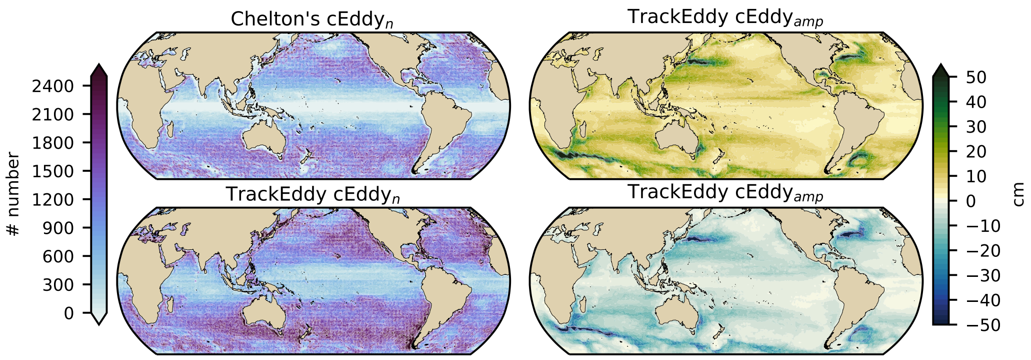

Figure 4. Ratios of the kinetic energy components. a)

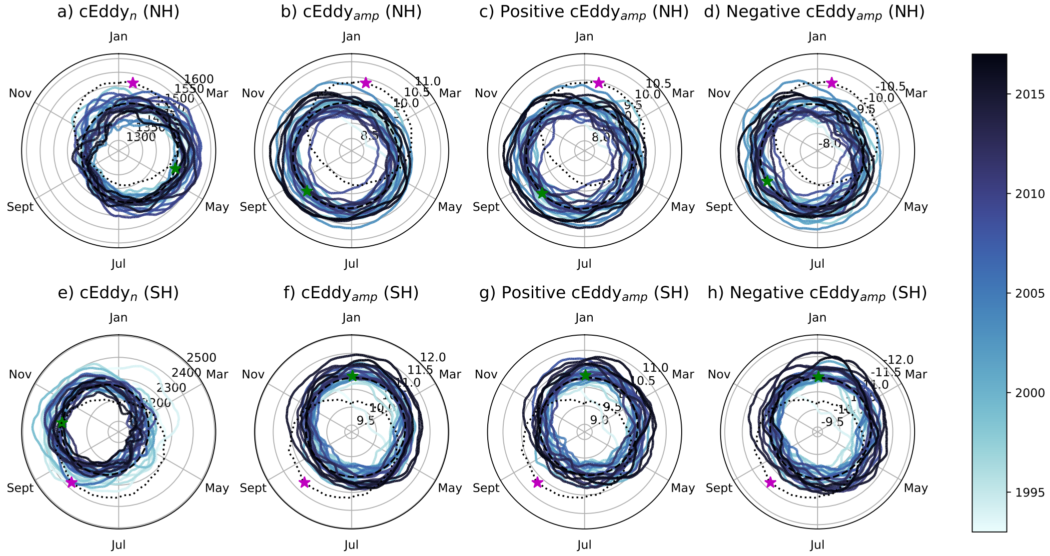

Figure 5. Dashed lines correspond to the seasonal climatology of the fields. Dotted lines show the climatology of the wind magnitude. The green and magenta stars show the maximum of the seasonal cycle for the kinetic energy components and the wind magnitude, respectively.

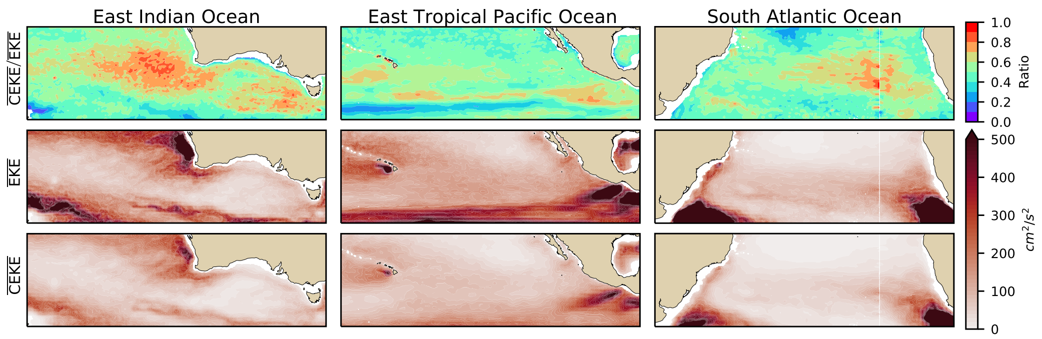

Figure 6. Climatology of regional statistics of the eddy field and coherent eddy field for the East Indian Ocean, East Tropical Pacific Ocean and South Atlantic Ocean. a-c Zoom to ratio of CEKE and EKE; d-f mean eddy kinetic energy ($\overline{\text{EKE}}$); g-i mean coherent eddy kinetic energy ($\overline{\text{CEKE}}$); j-k count of identified coherent eddies between 1993-2019; and l-n mean coherent eddy amplitude between 1993-2019.

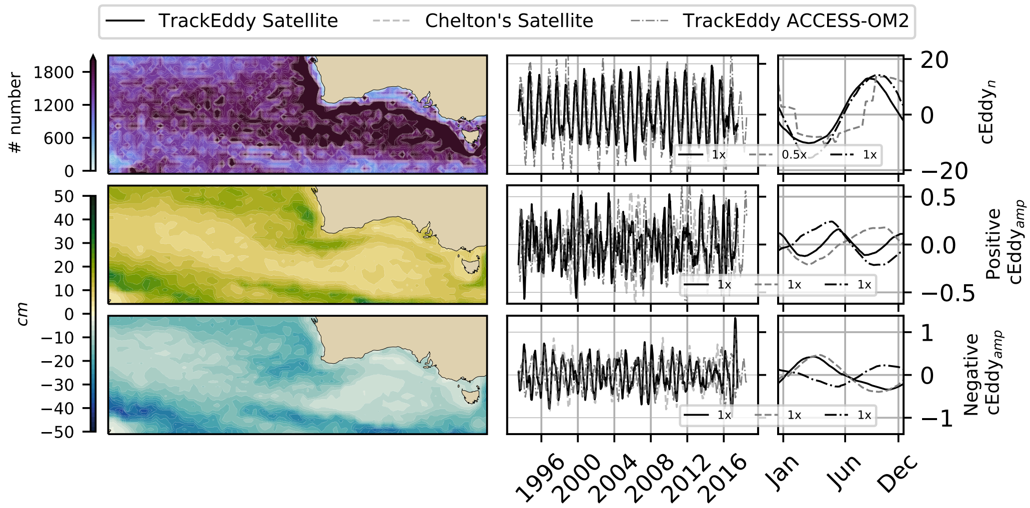

Figure 7. Climatology of regional statistics of the eddy field and coherent eddy field for the East Indian Ocean, East Tropical Pacific Ocean and South Atlantic Ocean. a-c Zoom to ratio of CEKE and EKE; d-f mean eddy kinetic energy ($\overline{\text{EKE}}$); g-i mean coherent eddy kinetic energy ($\overline{\text{CEKE}}$); j-k count of identified coherent eddies between 1993-2019; and l-n mean coherent eddy amplitude between 1993-2019.

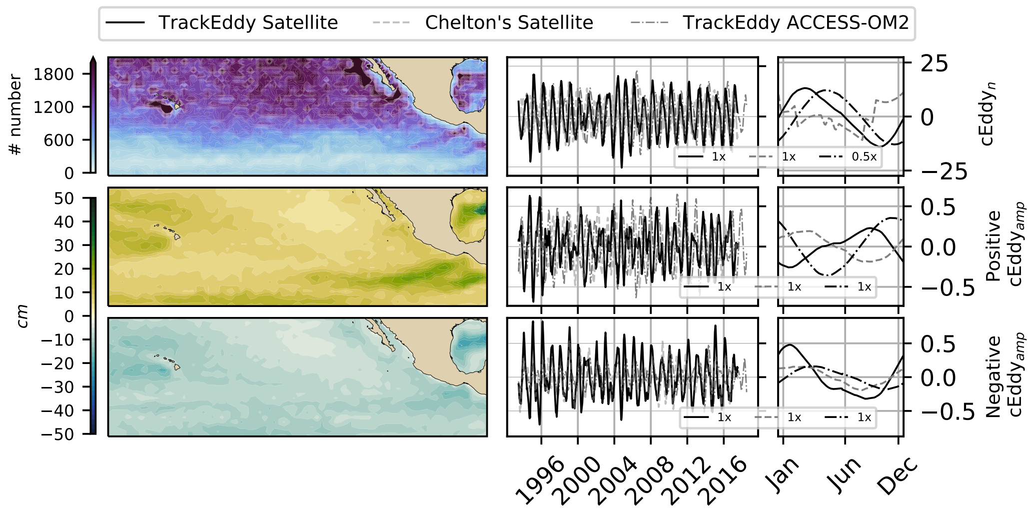

Figure 8. Climatology of regional statistics of the eddy field and coherent eddy field for the East Indian Ocean, East Tropical Pacific Ocean and South Atlantic Ocean. a-c Zoom to ratio of CEKE and EKE; d-f mean eddy kinetic energy ($\overline{\text{EKE}}$); g-i mean coherent eddy kinetic energy ($\overline{\text{CEKE}}$); j-k count of identified coherent eddies between 1993-2019; and l-n mean coherent eddy amplitude between 1993-2019.

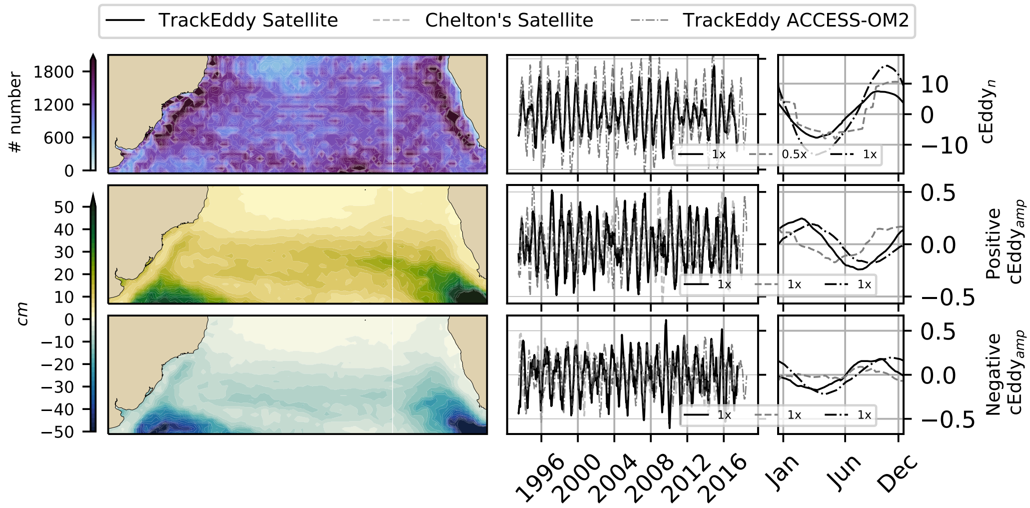

Figure 9. Climatology of regional statistics of the eddy field and coherent eddy field for the East Indian Ocean, East Tropical Pacific Ocean and South Atlantic Ocean. a-c Zoom to ratio of CEKE and EKE; d-f mean eddy kinetic energy ($\overline{\mathrm{EKE}}$); g-i mean coherent eddy kinetic energy ($\overline{\mathrm{CEKE}}$); j-k count of identified coherent eddies between 1993-2019; and l-n mean coherent eddy amplitude between 1993-2019.

4 Trends

5 Summary and Conclusions

Acknowledgments

References

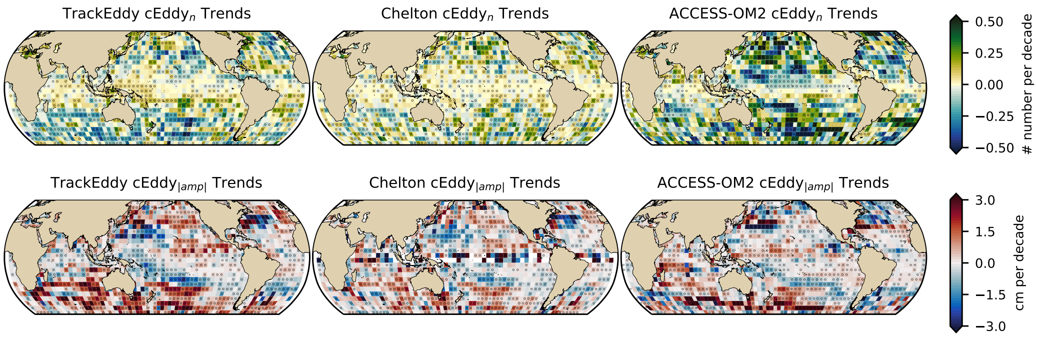

Figure 10. **Crop colorbar**Climatology of regional statistics of the eddy field and coherent eddy field for the East Indian Ocean, East Tropical Pacific Ocean and South Atlantic Ocean. a-c Zoom to ratio of CEKE and EKE; d-f mean eddy kinetic energy ($\overline{\mathrm{EKE}}$); g-i mean coherent eddy kinetic energy ($\overline{\mathrm{CEKE}}$); j-k count of identified coherent eddies between 1993-2019; and l-n mean coherent eddy amplitude between 1993-2019.